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This document summarizes the data from several studies on the number of traverse points specified by EPA Method 1. This summary is used as the basis for revising Method 1 to utilize a lesser number of traverse points.

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Emission Measurement Branch

Emission Standards and Engineering Division

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air, Noise, and Radiation
Office of Air Quality Planning and Standards
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BACKGROUND INFORMATION FOR PROPOSED REVISIONS TO REDUCE NUMBER OF TRAVERSE POINTS IN METHOD 1

INTRODUCTION

On December 23, 1971, the Environmental Protection Agency (EPA) published in the Federal Register (36 FR 24876) Method 1, which specifies the minimum number of traverse points required for velocity and particulate matter sampling from stationary sources. This method was later revised and published on August 18, 1977 (42 FR 41754).

During 1976, 1977, and 1980, several published reports[1-6] indicated that the number of traverse points could be reduced from those specified by Method 1. The results of these studies served as the basis for revising Method 1 to utilize a lesser number of traverse points. These studies and a 1961 study[7] are summarized below.

FLUIDYNE REPORT[1]

Fluidyne Engineering Corporation conducted its study under EPA Contract No. 68-02-1244. In this study, 27 velocity and 4 particulate profiles were obtained from a literature survey, laboratory-scale modeling, and field testing. The data were fitted by polynomial equations, and various traverse schemes were then compared against the value determined by integrating the polynomials over the cross-sectional area of the duct. The results of the study are summarized in Tables 1, 2, and 3. Table 1 summarizes the velocity relative errors based on 21 rectangular ducts, and Table 2 lists data from 6 circular stacks. Table 3 summarizes the particulate mass rate relative errors for four rectangular ducts.

TABLE 1. VELOCITY RELATIVE ERRORS FROM 21 RECTANGULAR DUCTS[1,2]

Matrix	No. of traverse points	Average relative error,[a] percent	95% tolerance region for average relative error,[b] percent
1 x 1	1	14.90	±50.59
2 x 2	4	4.01	±12.40
3 x 3	9	0.92	± 2.39
4 x 3	12	0.70	± 1.95
4 x 4	16	0.47	± 1.54
5 x 4	20	0.40	± 1.29
5 x 5	25	0.33	± 1.11
6 x 5	30	0.29	± 1.07
6 x 6	36	0.25	± 0.85
8 x 6	48	0.21	± 0.82

[a] Average of absolute relative errors.

[b] Considered signs in calculations.

TABLE 2. VELOCITY RELATIVE ERRORS FROM SIX CIRCULAR STACKS[1]

No. of traverse points		No. of stacks having maximum error less than:			
One diameter	Total[a]	6.0%	4.0%	2.0%	1.0%
4	8	6	5	1	1
8	16	6	6	5	3
12	24	6	6	5	4
16	32	6	6	5	4

[a] Two perpendicular diameters.

TABLE 3. PARTICULATE MASS RATE ERRORS FROM FOUR RECTANGULAR DUCTS[1]

Matrix	No. of traverse points	Average relative error,[a] percent	95% tolerance region for average relative error,[b] percent
1 x 1	1	12.51	±39.35
2 x 2	4	8.37	±27.33
3 x 3	9	2.14	± 6.81
4 x 3	12	1.58	± 4.96
4 x 4	16	1.02	± 2.85
5 x 4	20	0.82	± 2.21
5 x 5	25	0.58	± 1.60
6 x 5	30	0.48	± 1.27
6 x 6	36	0.38	± 1.07
8 x 6	48	0.20	± 0.58

[a] Average of absolute relative errors.

[b] Considered signs in calculations.

TRW REPORT[3]

This study was conducted by TRW Systems Group under EPA Contract No. 68-02-1412. As part of this project, 18 velocity traverses were examined. A curve fitting technique was used to generate the data, which were then compared to those obtained from a 25- by 21-point matrix. The report concluded that there was no notable increase in accuracy for matrices in excess of 16 traverse points and that the average velocity error for the 16-point traverse was 1.4 percent with an expected standard deviation of less than 2 percent.

ENTROPY REPORTS[4,5]

Two studies were conducted by Entropy Environmentalists, Inc., under EPA Contract No. 68-01-3172. One study dealt with velocity, and the other dealt with particulate traverses. For the velocity study, data from some 150 circular ducts and more than 120 rectangular stacks were evaluated. In the analysis, however, each traverse line was considered to be a separate test. Each traverse line was fitted to a curve, and the various number of traverse points were compared to 24 points. The results of this study are summarized in Table 4.

The particulate study was similar to that of the Fluidyne study except the basis for comparison was the 7- by 7-point matrix. The results are summarized in Table 5.

TABLE 4. VELOCITY ERRORS FROM 150 CIRCULAR STACKS AND 120 RECTANGULAR DUCTS[4]

No. of traverse points on a line	Average relative error, percent[a]	
	Circular	Rectangular
2	7.19	1.90
4	2.76	0.50
6	1.27	-
8	1.28	0.53
12	0.08	0.16
16	0.09	0.09
20	0.02	-
24	-	-

[a] Average of absolute errors.

Note: Tolerance regions not calculated because of insufficient information in report.

TABLE 5. PARTICULATE MASS RATE ERRORS FROM 10 RECTANGULAR DUCTS[5]

Matrix	traverse points	Average relative error,[a] percent	95% tolerance region for average relative error,[b] percent
3 x 3	9	3.00	±8.68
4 x 3	12	3.11	±7.60
4 x 4	16	2.60	±7.68
5 x 4	20	3.05	±9.61
5 x 5	25	1.89	±5.12
6 x 5	30	1.30	±4.13
6 x 6	36	1.51	±4.29
7 x 6	42	1.45	±5.00
12 x 4	48	1.30	±3.81
7 x 7	49	-	-

[a] Average of absolute relative errors.

[b] Considered signs in calculations.

EMISSION MEASUREMENT BRANCH REPORT[6]

The Emission Measurement Branch (EMB) of EPA conducted a study to determine the least number of sampling points for particulate mass flow rate in circular stacks. Three different particulate profiles were studied, and various numbers of traverse points on a line were compared to a 24-point traverse. The results are summarized in Table 6.

TABLE 6. PARTICULATE MASS RATE ERRORS FROM THREE TYPES DISTRIBUTIONS IN CIRCULAR STACKS[6]

No. of traverse points on a line	Percentage error		
	U-shaped	Skewed	Parabolic
2	±0.4	+18.0	-0.8
4	±0.4	+37.8	+0.4
6	-0.4	+ 3.6	+0.4
8	+0.4	0	+0.4
10	0	+ 0.9	0
12	+0.4	+ 4.5	0
14	+3.1	+ 0.9	0
16	+0.4	0	0
18	0	0	0
20	+0.4	+ 1.8	0
22	+0.4	0	-0.4
24	-	-	-

BRITISH COAL UTILISATION RESEARCH ASSOCIATION[7]

A report on a study performed by the British Coal Utilisation Resesarch Association (BCURA) is included here because it covers a wide range of conditions in rectangular ducts, including steep gradients of solids flow. The bias due to sampling a limited number of points was calculated from different mass flow profiles found in a number of plants. The results are summarized in Table 7.

TABLE 7. MAGNITUDE OF BIAS DUE TO SAMPLING AT A FINITE NUMBER OF SAMPLING POINTS

No. of sampling points	95% confidence limits of bias expressed as percentage of true value
1	±42
4	±13
8	± 5.0
9	+ 3.9

DISCUSSION AND CONCLUSIONS

The summaries of the data from the various reports clearly show that the number of traverse points can be reduced from the 48 points specified in Method 1 with no significant loss in measurement accuracy on an average. The average accuracy improves dramatically up to about eight or nine points, then improves very slowly beyond a total of nine traverse points. For example, Table 1 shows that the average absolute relative error for velocity measurements decreases rapidly from 14.90 to 0.92 when the number of traverse points goes

from 1 to 9, while the error changes from 0.92 to 0.21 percent when the number of traverse points is increased from 9 to 48. This effect is graphically illustrated in Figure 1 for the data presented in Tables 1 and 3.

The 95 percent tolerance region for nine particulate or velocity traverse points are conservatively estimated to be ±10 percent. To reduce the tolerance region to ±5 percent, the number of traverse points must be increased to 16 for velocity and 24 for particulate mass flow rate measurements. The effect of the 95 percent tolerance region against the number of traverse points is graphically illustrated in Figure 2.

Since none of the studies considered the effect of the number of traverse points on accuracy in relation to the number of equivalent diameters from points of disturbances, an arbitrary decision was made to leave unchanged the present 8-diameter-downstream and 2-diameter-upstream criteria and to limit the decrease of the number of sampling points to the 2 to 4 diameters downstream and 0.5 to 1 diameter upstream.

The proposed revisions to Method 1 are given in Figures 3 and 4.

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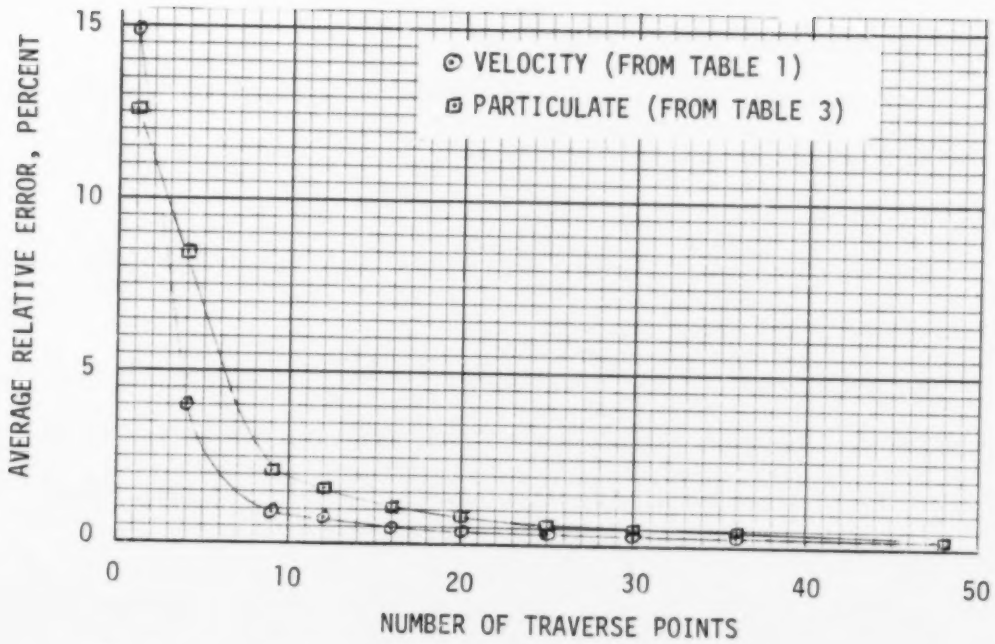

Figure 1. Average relative error vs. number of traverse points.

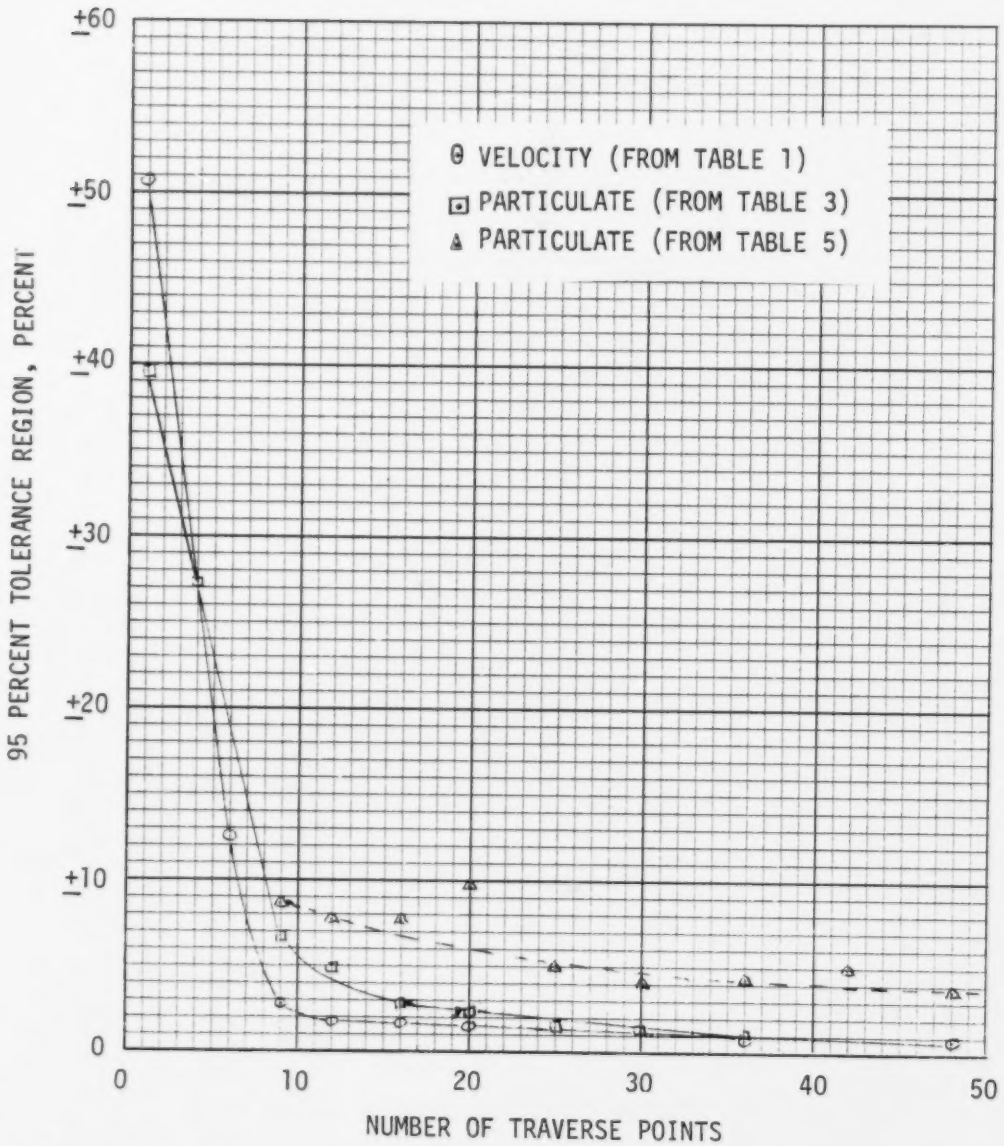

Figure 2. 95 percent tolerance region vs. number of traverse points.

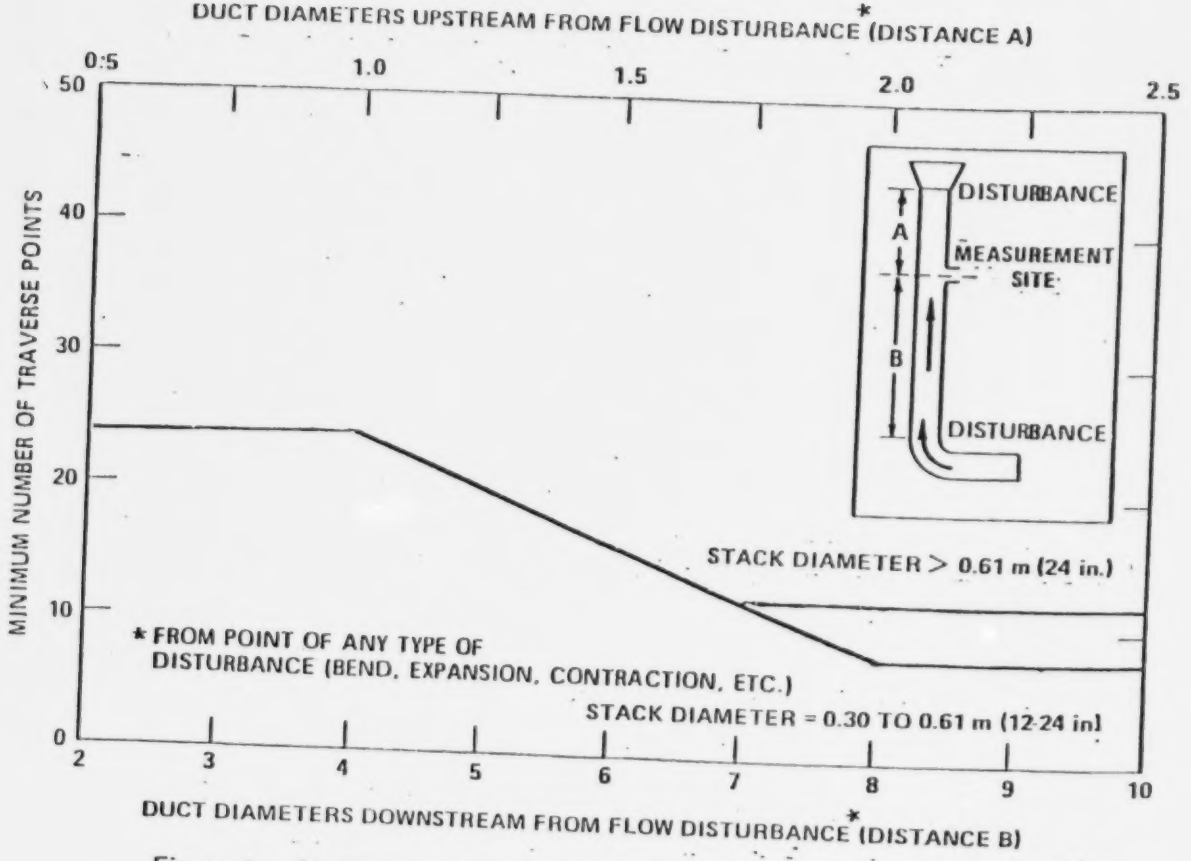

Figure 3. Minimum number of traverse points for particulate traverses.

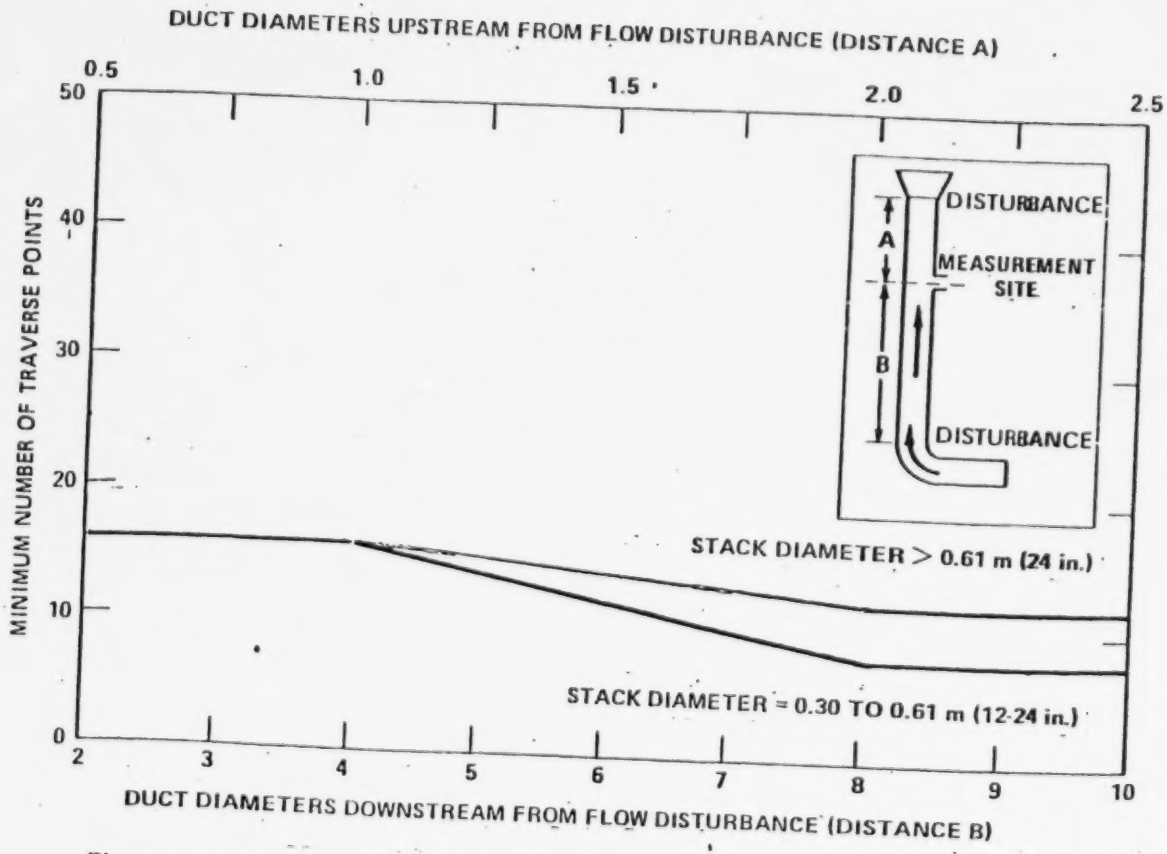

Figure 4. Minimum number of traverse points for velocity (nonparticulate) traverses.